CHAPTER 8

ELECTROSTATIC PRECIPITATORS

8-1. Electrostatic precipitator (ESP)

An electrostatic precipitator is a device which removes particles from a gas stream. It accomplishes particle separation by the use of an electric field which:

— imparts a positive or negative charge to the particle,

— attracts the particle to an oppositely charged plate or tube,

— removes the particle from the collection surface to a hopper by vibrating or rapping the collection surface.

8-2. Types of electrostatic precipitators

a. Two stage ESPs. Two stage ESPs are designed so that the charging field and the collecting field are independent of each other. The charging electrode is located upstream of the collecting plates. Two stage ESPs are used in the collection of fine mists.

b. Single stage ESPs. Single stage ESPs are designed so that the same electric field is used for charging and collecting particulate s Single stage ESPs are the most common type used for the control of particulate emissions and are either of tube or parallel plate type construction. A schematic view of the tube and parallel plate arrangement is given in figure 8-1.

(1) The tube type precipitator is a pipe with a discharge wire running axially through it. Gas flows up through the pipe and collected particulate is discharged from the bottom. This type of precipitator is mainly used to handle small gas volumes. It possesses a collection efficiency comparable to the parallel plate types, usually greater than 90 percent. Water washing is frequently used instead of rapping to clean the collecting surface.

(2) Parallel plate precipitators are the most commonly used precipitator type. The plates are usually less than twelve inches apart with the charging electrode suspended vertically between each plate. Gas flow is horizontal through the plates.

8-3. Modes of operation.

All types of ESPs can be operated at high or low temperatures, with or without water washing (table 8-1).

a. Hot precipitation. A hot precipitator is designed to operate at gas temperatures above 600 degrees Fahrenheit and is usually of the single stage, parallel plate design. It has the advantage of collecting more particulate from the hot gas stream because particle resistance to collection decreases at higher temperatures. The ability to remove particles from the collection plates and hoppers is also increased at these temperatures. However, hot precipitators must be large in construction in order to accommodate the higher specific volume of the gas stream.

b. Cold precipitation. Cold precipitators are designed to operate at temperatures around 300 degrees Fahrenheit. The term “cold” is applied to any device on the low temperature side of the exhaust gas heat exchanger. Cold ESPs are also generally of the single stage, parallel plate design. They are smaller in construction than hot precipitator types because they handle smaller gas volumes due to the reduced temperature. Cold precipitators are most effective at collecting particles of low resistivity since particle resistance to collection is greater at lower temperatures. These precipitators are subject to corrosion due to the condensation of acid mist at the lower temperatures.

c. Wet precipitation. A wet precipitator uses water to aid in cleaning the particulate collection plates. It may employ water spray nozzles directed at the collection plates, or inject a fine water mist into the gas stream entering the precipitator. Wet precipitators enhance the collection efficiency of particulates by reducing reentrainment from the collection plates. Care should be taken so that water addition does not lower gas temperature below the dewpoint temperature, thus allowing the formation of acids. A wet precipitator can be of either plate or tube type construction.

8-4. Applications

Electrostatic precipitators are among the most widely used particulate control devices. They are used to control particulate emissions from the electric utility industry, industrial boiler plants, municipal incinerators, the non-ferrous, iron and steel, chemical, cement, and paper industries. It is outside the scope of this manual to include all of these application areas. Only applications to boilers and incinerators will be reviewed.

a. Boiler application. Parallel plate electrostatic precipitators are commonly employed in the utility industry to control emissions from coal-fired boilers. Cold type precipitators are the prevalent type because

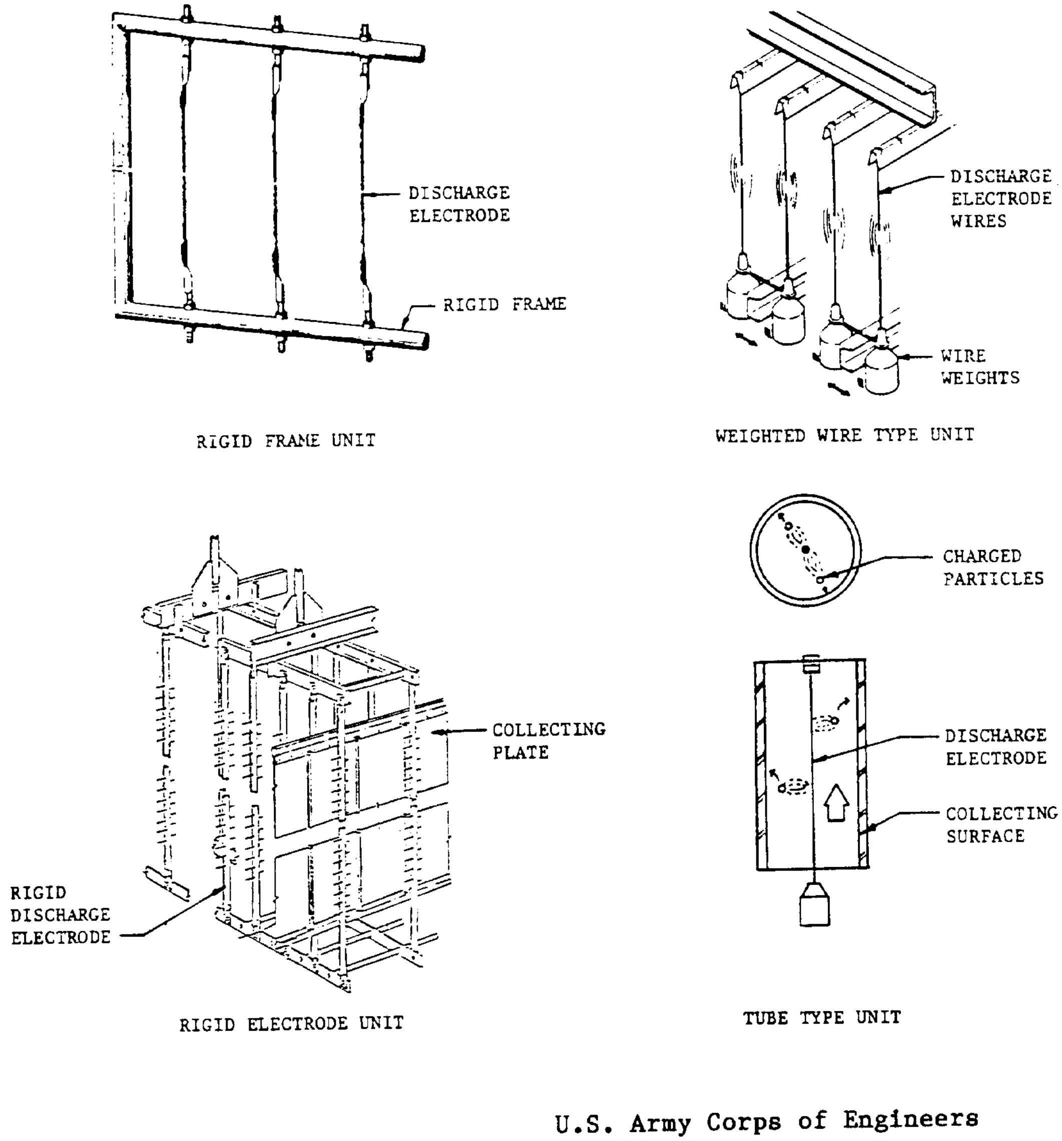

Figure 8–1. Schematic views of flat end tubular surface type electrostatic precipitators

they are most easily retrofitted. In the design of new installations, the use of hot precipitators has become more common, because of the greater use of lower sulfur fuels. Low sulfur fuels have higher particle resistivity and therefore particulate emissions are more difficult to control with cold precipitation. Figure 8-2 may be used for estimating whether hot precipitators or cold precipitators should be selected for a particular sulfur content of coal.

b. Wood refuse boiler applications. An ESP can be used for particulate collection on a wood fired boiler installation if precautions are taken for fire prevention. The ESP should be preceded by some type of mechanical collection device to prevent hot glowing char from entering the precipitator and possibly starting a fire.

c. Incinerator application. Until relatively recently, ESPs were used for pollution control on incineration units only in Europe. In the United States, however, the ESP is now being viewed as one of the more effective methods for the control of emissions from incinerators. The major problem associated with the use of precipitators on incinerators is high gas temperatures. Temperatures up to 1800 degrees Fahrenheit can be encountered at the incinerator outlet. These temperatures must be reduced before entering a precipitator. Several methods can be used to accomplish this temperature reduction:

— mixing of the gas with cooler air;
— indirect cooling such as waste heat boilers,
— evaporative cooling in which droplets of water are sprayed into the gas.

TABLE 8-1
OPERATING CHARACTERISTICS OF PRECIPITATORS

Type	Operating Temperature °F	Dust Resistivity at 300°F ohm-cm	Gas Flow ft^3/min.	Pressure Drop in. of water	Design Collection Efficiency % by weight	Application	Other
Hot ESP	600+	greater than 10^{12}	100,000+	less than 1"	Usually 90+ can go to 99+	Before pre-heater in boilers, incinerator, industrial	Can collect high resistivity dust. Has higher gas flow and is large in size. Corrosion usually not a problem.
Cold ESP	300	less than 10^{10}	100,000+	less than 1"	Usually 90+ Can go to 99+	After pre-heater in boilers, incinerator, industrial	Limited to dust resistivities lower than 10^{10} ohm-cm. Corrosion can be a problem.
Wet ESP	300-	greater than 10^{12} below 10^4	100,000	less than 1"	Usually 90+ Can go to 99+	industrial, boilers, incinerator	Useful for high or low resistivity dust collection. Corrosion usually not a problem.

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8-5. Performance

The performance of an electrostatic precipitator is predominantly affected by particle resistivity, particle size, gas velocity, flow turbulence, and the number of energized bus sections (electrically independent sections) in operation.

a. Particle resistivity. Particle resistivity is an electrical property of a particle and is a measure of its resistance of being collected. Particle resistivity is affected by gas temperature, humidity, sodium content, and sulfur trioxide (SO_3) content. See figure 8-3.

b. Collection plate area. Collection plate area, and gas volume, affect electrostatic precipitator performance. The basic function relating these factors is shown in equation 8-1.

$$CE = 1 - e - (\frac{A_c}{V_g} \times w)^e \qquad \text{(eq. 8-1)}$$

Where: CE = collection efficiency
A_c = collection plate area in square feet (ft^2)
V_g = gas flow rate in cubic feet/minute (ft^3/min)
w = migration velocity or precipitation rate parameter, feet/minute (ft/min).

c. Bus sections. The number of energized bus sections in a precipitator has an effect upon collection efficiency. A power loss in one energized bus section will reduce the effectiveness of the precipitator. See figure 8-4.

d. Turbulence. Turbulence in the gas flow through an electrostatic precipitator will decrease its collection efficiency. For proper operation all segments of the flow should be within 25 percent of the mean flow velocity.

8-6. Description of components

a. Shell. The shell of an ESP has three main functions: structural support, gas flow containment, and insulation. Shell material is most commonly steel; if necessary, insulation can be applied to the exterior to prevent heat loss. Brick or concrete linings can be installed on shell interiors if gas stream corrosion of the metal may occur. Corrosion resistant steel can also be used as a lining, but the cost may be uneconomical and at times prohibitive. Since the shell is also used for structural support, normal civil engineering precautions should be taken in the design.

b. Weighted wire discharge electrodes. Wires vary in type, size, and style. Provision is made to keep the

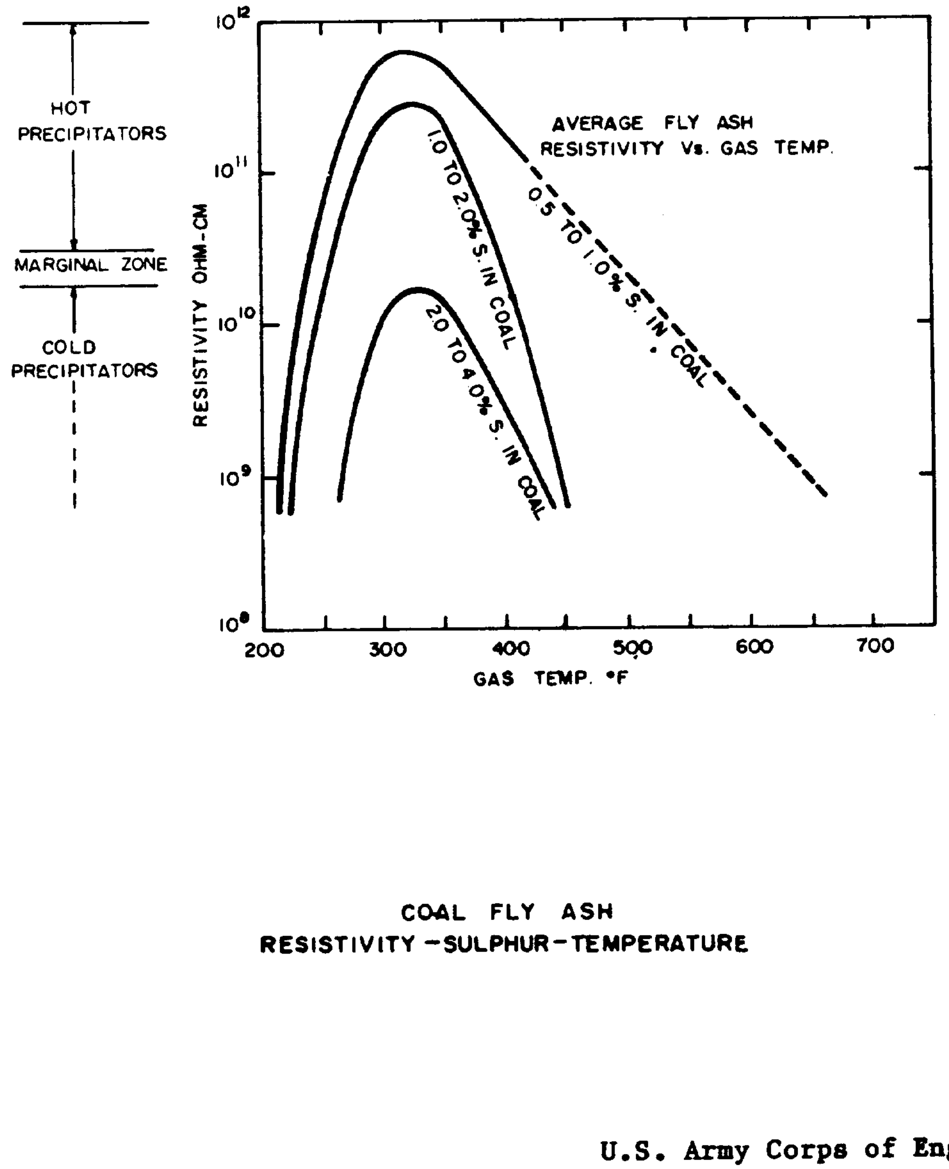

Figure 8–2. Operating ranges for hot/cold electorstatic precipitators

discharge wire from displacement by attachment to a suspended weight. The wires can be made stiff consisting of a formed sheet, or they can be simple variations of the normal straight round wire such as being barbed or pronged. Steel alloys are commonly used for wire construction, but actually any conducting material with a proper configuration and sufficient tensile strength can be used.

(1) *Rigid frame discharge electrodes.* Rigid frame designs incorporate a framework which supports the discharge electrodes. By using the rigid frame design the need for wire weights is eliminated since the frame keeps the wires properly supported and aligned.

(2) *Rigid electrodes.* The rigid electrode design uses electrodes that have sufficient strength to stay in alignment their entire length. The electrodes are supported from the top and kept in alignment by guides at the bottom. Rigid electrodes are the least susceptible to breakage.

c. Collection electrodes. There are numerous types of collection electrodes designed to minimize reentrainment and prevent sparking. The material used in construction, however, must be strong enough to withstand frequent rapping. In order to insure correct electrode application, it is wise to see if the electrode chosen has exhibited good performance at similar installations.

d. Hoppers. A hopper is used to collect ash as it falls from the precipitator. The hopper should be designed using precautions against corrosion in the precipitator as any leakage due to corrosion will enhance entrainment. If the precipitator is dry, a hopper angle should be chosen that will prevent bridging of collected dust.

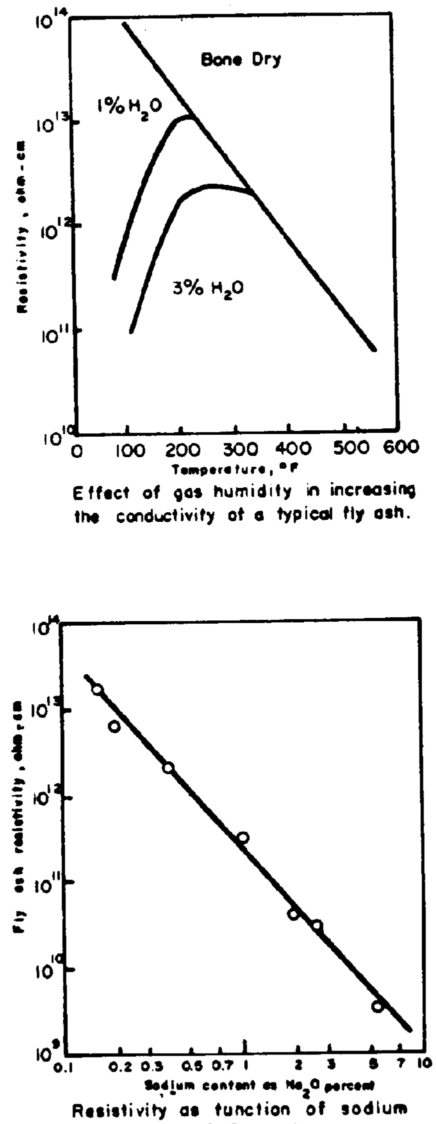

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Figure 8–3. Factors affecting particle resistivity

Hoppers must be sized so that the amount of dust collected over a period of time is not great enough to overflow and be reentrained. Seals also must be provided around the outlet to prevent any air leakage. If the precipitator is wet, the hopper should allow removal of sludge in a manner compatible with the overall removal system. In general the collected dust in the hoppers is more free flowing when kept hot. The hop-pers should be insulated and should have heaters to maintain the desired temperatures. Hoppers heaters will also prevent the formation of acids that may occur at low temperatures. Provisions should be made for safe rodding out the hoppers should they become plugged.

e. Rappers. Rappers are used to remove dust from the discharge and collection electrodes. Rappers are usually one of two types, impulse or vibrator. The vibrator type removes dust from the discharge electrode by imparting to it a continuous vibration energy. They are used to remove dust from the collection electrodes. Impulse rappers consist of electromagnetic solenoids, motor driven cams, and motor driven hammers. Important features to note in choosing rappers are long service life without excessive wear and flexible enough operation to allow for changing precipitator operating conditions. Low intensity rapping of plates (on the order of one impact per minute) should be used whenever possible to avoid damage to the plates. visual inspection of the effect of rapping on reentrainment is usually sufficient to determine a good rapping cycle.

f. High tension insulators. High tension insulators serve both to support the discharge electrode frame and also to provide high voltage insulation. The materials used are ceramic, porcelain, fused silica and alumina. Alumina is the most common. The insulators must be kept clean to prevent high voltage shorting and resultant equipment damage. Compressed air or steam can be used for this purpose.

g. Four point suspension. Rigid electrode and rigid frame units may utilize a four point suspension system to support the discharge electrode framework in each chamber. This type of suspension system assures a better alignment of the discharge and collection electrodes. This in turn provides a more consistent operation.

h. Distribution devices. Perforated plates, baffles or turning vanes are usually employed on the inlet and outlet of an ESP to improve gas distribution. Improper distribution can cause both performance and corrosion problems. These distribution devices may require rappers for cleaning.

i. Model testing. Gas flow models are used to determine the location and type of distribution devices. The models may include both the inlet and outlet ductwork in order to correctly model the gas flow characteristics. Gas flow studies may not be required if a proven precipitator design is installed with a proven ductwork arrangement.

8-7 Control systems

The electric power control system is the most important component system of any E SP. The basic components of this system are: step-up transformer; high voltage rectifier; voltage and amperage controls; and sensors.

a. Automatic power control. By utilizing a signal from a stack transmissionmeter the power level in the precipitator can be varied to obtain the desired performance over a wide range of operating conditions.

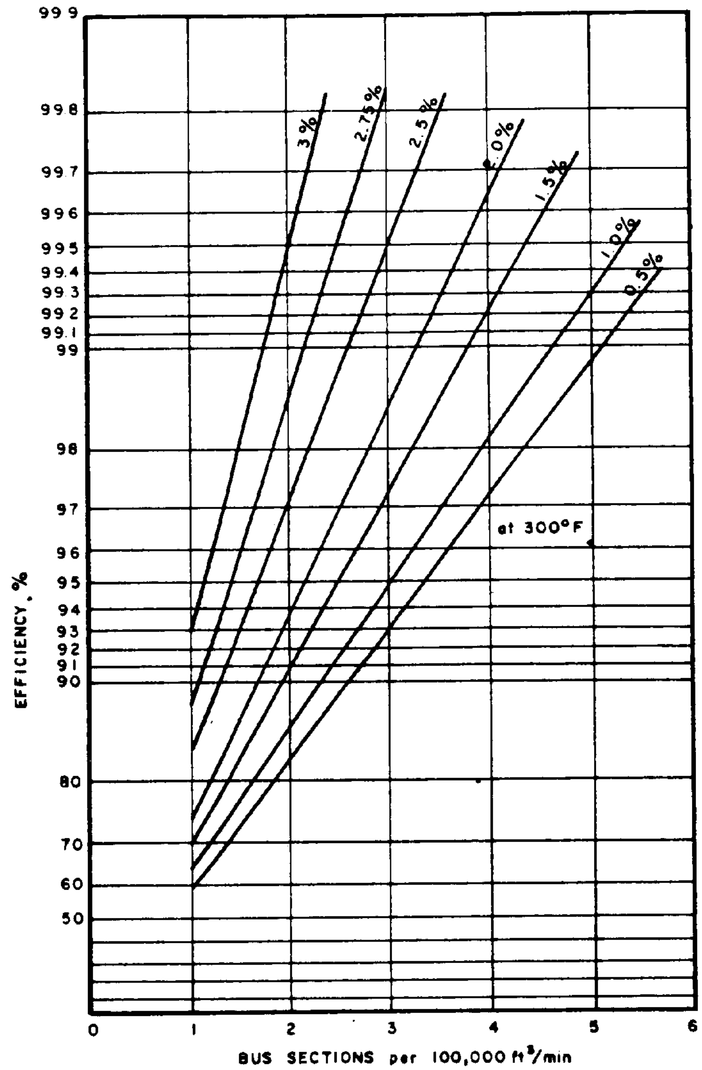

Figure 8–4. Bus sections vs. efficiency for different sulfur percentages in coal.

b. High voltage transformer. The standard iron core transformer is the only instrument generally used to step-up the input voltage. The only care that need be taken is that the transformer is of superior quality and able to put out the quantity of voltage required by the precipitator. Transformers are designed to withstand high ambient temperatures and electrical variations induced by sparking. For high temperature operation, the most common transformer cooling method is liquid immersion.

c. High voltage rectifier. Silicon rectifiers are the latest advance in rectifying circuitry. They are solid state devices which have a few of the disadvantages of the other types of rectifiers. An assembly of silicon rectifiers is used for lower rated current sets, typically 500 miliamperes (mA).

d. Voltage and amperage controls. Controls are needed to insure that the precipitator is supplied with the maximum amount of voltage or power input, and to control the effects of sparking. The most modern method of accomplishing these aims is through the use of silicon controlled rectifiers (SCR). Other modern control devices are saturable reactors and thyristors (four element, solid state devices). Voltage control can also be accomplished by tapped series dropping resistors, series rheostats, tapped transformer primaries, and variable inductances.

e. Auxiliary control equipment. As with any control device, gas flow should be monitored either by read-out of amperage from the fans or by measuring static pressure. It is also useful to have sensors which measure the sulfur dioxide (SO_2) concentration and temperature of the inlet gas stream in order to determine the dew-point temperature.

8-8. Advantages and disadvantages

a. Advantages.

(1) The pressure drop through a precipitator is a function of inlet and outlet design and precipitator length. Pressure drop rarely exceeds 0.5 inches, water gauge.

(2) The ESP can be designed to have 99.9 + percent collection efficiency.

(3) Silicon control rectifiers and other modern control devices allow an electrostatic precipitator to operate automatically.

(4) Low maintenance costs.

b. Disadvantages.

(1) Due to the size of a typical ESP and the erratic nature of most processes (especially if frequent start-up and shutdowns occur) the temperature in different parts of the structure could at times drop below the acid dew point. Corrosion can cause structural damage and allow air leakage.

(2) An ESP is sensitive to its design parameters. A change in the type of coal used, for example, could drastically affect performance.

(3) High capital costs.

(4) If particulate emission concentrations are high, a mechanical precleaner may be necessary.

(5) High voltages are required.

(6) No SO_2 control is possible with an ESP.